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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, Washington 98101

June 13, 2002

Reply To
Attn Of: ORC-158

FILE COPY

VIA FIRST CLASS MAIL

Mark W. Schneider
Perkins Coie LLP
1201 Third Avenue, Suite 4800
Seattle, Washington 98101-3099

Re: Container Properties/Former Rhone-Poulenc, Inc. Facility

Dear Mr. Schneider:

I am responding to the letter dated May 6, 2002, that you sent to my colleague, Charlie Ordine. As the EPA lawyer assigned to the Rhone-Poulenc Facility RCRA Corrective Action matter, and given the subject of your letter, I thought it appropriate that I respond.

As Charlie has told you, those of us working on the Rhone-Poulenc team were not aware that Boeing owns the slip bed of Slip 6. Therefore, we did not realize that notice or access should be sought from Boeing prior to conducting our field work in the slip in connection with the Rhone-Poulenc matter. As Charlie has indicated, it is EPA's routine practice to seek access from private property owners when in the course of its regulatory activity it needs to enter onto their property. EPA lacks information regarding Boeing's property interest in slip 6, however. Thus, EPA is requesting documentation from Boeing clarifying the extent of Boeing's property interest in relation to Slip 6. Both a legal description and a map depicting the extent of Boeing's property interest, as well as a statement of Boeing's understanding of the extent of its interest would help us to ensure that we honor our access policy with respect to Boeing's interest in slip 6 in the future. Regarding EPA's request for a statement describing Boeing's understanding of the extent of its interest, EPA is seeking to understand specifically those activities that we might undertake that would, in Boeing's view, require access from or notice to Boeing. For example, the activities in which EPA might engage in Slip 6 might include diving underwater (involving either sampling of water or sediment, or simply observations), placing temporary lines and floats (to insure diver safety), boating on the water, and walking on the mud flats on the Rhone-Poulenc side of the slip during low tide. EPA would like to have a full understanding of Boeing's view of which of those activities should occasion access from and/or notification to Boeing.

We are enclosing the Field Sampling Plan and the EPA Region 10 Dive Plan prepared for the April 2 and 3, 2002 activities. EPA has not yet prepared a report of its activities at this time. When a report is prepared, we will forward it to you.

Please contact me if you have any questions at (206) 553-8311. We look forward to hearing from you.

Sincerely,

Jennifer G. MacDonald

Jennifer G. MacDonald
Assistant Regional Counsel

Enclosures

cc: Charles Ordine, Esq.

EPA REGION 10 DIVE PLAN

From: Bruce Duncan, Divemaster

Date of Request: March 26, 2002

Approval

Thru: Rob Pedersen, UDO ______________
To: Jan Hastings, Director, OEA ______________
Keven McDermott, OEA ______________

Project: Rhone Poulenc (RCRA) ground water discharge evaluation

Dates of Dive: April 2 and 3, 2002

Location: Lower Duwamish River, Seattle, WA

Scientific Objectives: Support RCRA Program by collecting information on the hydraulic connection between the facility and the Duwamish River

Scientific Observations/Data collection: Shallow subtidal - Day 1 - Tuesday, April 2
1. Place 10 seepage meters on two 100m transect lines (5 on each line, about 25m apart) in approximately 20 ft water depth at beginning of a falling tide (tide should fall about 10 ft). Transects will be deployed at right angles to each other into the slip and along the Duwamish.
2. After about 1 hour, collect and replace 5 bags; record volume collected, use field equipment to measure DO, pH, conductivity, and copper (free and total)
3. After another hour or so, depending on results from step 2, collect and replace 5 more bags and make similar measurements as in step 2.
4. In the afternoon, collect and replace all 10 bags and leave overnight

Day 2 - Wednesday, April 3
1. Collect and replace all 10 bags and analyze seepage water as described in step 2 for Day 1
2. Test other sampling devices: push probes; underwater manometer (as a function of bucket insertion depth); mini-piezometers

Record locations using AquaMap in diver station only mode if the transponders are not likely to be shielded. Otherwise, GPS will be used

Diver-collected samples and observations will be made at the same time EPA hydrogeologists are obtaining push probe and other samples of GW in the intertidal zone.

Pollution Sources: Contaminated sediment (expect PCBs, metals, PAHs, pesticides in low to moderate concentrations - do not expect any free product). Storm drains and CSO during/after storm events. This site has high pH (>11), copper, toluene in wells near the waterway. Dilution within the ground water and within the Duwamish reduce this concern as an exposure to divers.

Decontamination Required: Rinse of divers on swim step with clean boat water. Clean and/or isolate any obviously contaminated equipment (e.g., over-gloves, swim fins). Follow-up soaking and cleaning in dive locker, as needed.

Potential Hazards: Boat traffic, low visibility, underwater hazards, river surface current.

Maximum Expected Water Depth: Less than 30ft and ideally between 10 and 20 ft.

Maximum Expected Water Current: Low to moderate at our operational depths near the shoreline. We will be out of the main channel but diving on a falling tide and along transect lines.

Diving Platform: EPA Monitor.

Divemaster: Bruce Duncan **Divers:** Day 1 (Tues April 2): C Schulze, B Duncan, J Goulet, B Hill, L Macchio

Cox'n: Curt Black

backup: JG may leave early, BD will fill in when he leaves
Day 2 (Wed April 3): C Schulze, B Duncan, R Pedersen, S Sheldrake
backup: B Hill

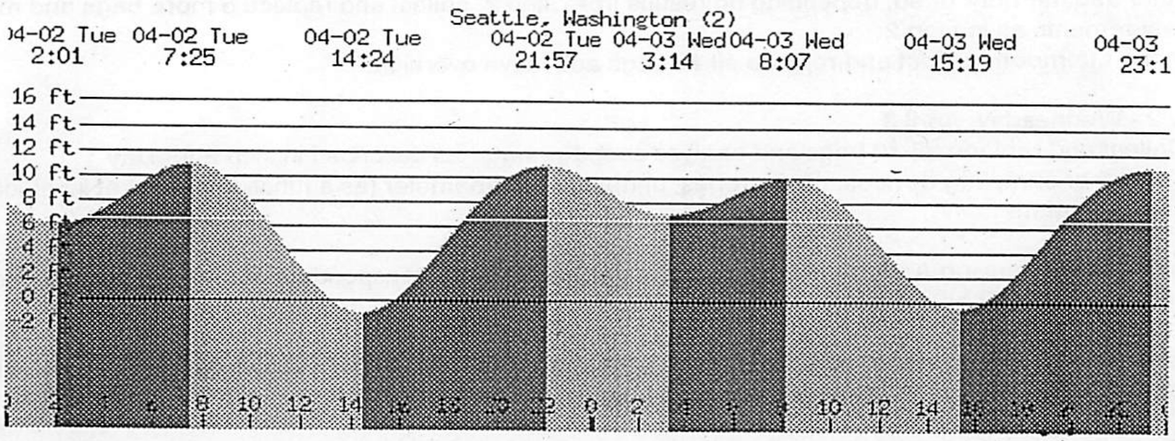
Tender: divers
Hydrogeologists (on shore): Rene Fuentes (shore team leader, may have RCRA personnel as well)
Others: We may have another person from OEA or RCRA on board to assist with sample processing and analysis

Security Issues/Traffic Lanes - Notify USCG of dive plan/operations: __X__Yes____No___N/A
Advanced notification of USCG for dives near sensitive areas (e.g., port facilities, bridges) or in high traffic lanes/ areas: Call 24hr. CG Marine Safety Office **206-217-6230**. Operations near DOD facilities - contact facility directly.

Proposed Schedule: Equipment set-up and load the van at 14:00 (2:00 pm) on day prior to day1. Day 1: Meet the EPA Monitor (location tbd) by 09:00. Day 2: Meet Monitor at 9:00 am or earlier (tbd)

TIDAL INFORMATION: Diving on falling tide in 10-20 ft water depth
2002-04-02 Tue 7:25 PST 10.87 feet High Tide
2002-04-02 Tue 14:24 PST -1.05 feet Low Tide

2002-04-03 Wed 8:07 PST 9.90 feet High Tide
2002-04-03 Wed 15:19 PST -0.52 feet Low Tide



Source of EMERGENCY TRANSPORTATION: local ambulance service - dial 911.
Nearest MEDICAL Facility: Virginia Mason Hospital - 206-583-6433 (Chamber phone is 206-583-6543)
Address: admission is through the Emergency Room on Spring Street at the corner of Terry and Spring streets
Nearest HYPERBARIC Facility: Virginia Mason, (See note 2 below) - 206-583-6543
Address: Terry and Spring Street, Seattle (admission is through the Emergency Room on Spring Street)

Notes:

(1) **Emergency helicopter transport** in Puget Sound is available through the **U.S. Coast Guard** (Channel 16 or telephone 220-7001 ***or *CG*** in Seattle).

(2) **Primary Hyperbaric Chamber** is located at the **Virginia Mason Hospital** (admission is through the Emergency Room on Spring Street at the corner of Terry and Spring streets; E.R. phone 583-6433, Chamber phone, 583-6543). **Alternative Hyperbaric Chambers** are the U.S. Naval Torpedo Station (Keyport, (206) 396-2522/2563 or after hours (206) 396-2551/2553). Although chambers are on site at NOAA, victims of barotrauma will be transported to Virginia Mason.

(3) **Diver's Alert Network** provides 24-hr medical advice at telephone 1-919-684-8111, for other business during normal working hours use 1-919-684-2948.

FIELD SAMPLING PLAN

FOR

Rhone-Poulenc Site
Duwamish River, Tukwila, WA

Prepared By US EPA Region 10
1200 Sixth Ave.
Seattle, WA 98101

Date: 04/01/02
Revision: 3

APPROVAL OF FIELD PLAN

Project Manager: Rene´ Fuentes Rene´ Fuentes Date: 04/01/02
USEPA, Office of Environmental Assessment

Field Sampling : Rene´ Fuentes, Bernie Zavala (OEA, Hydrogeologists)
Region 10 Dive Team
Christy Brown, RCRA Project Manager

TABLE OF CONTENTS

1 PROJECT MANAGEMENT

1.1 Distribution List

Rene´ Fuentes	Hydrogeologist
Bernie Zavala	Hydrogeologist
Christy Brown	RCRA Site Project Manager
Bruce Duncan	Ecologist/Dive Team coordinator

1.2 Project/Task organization

1.2.1 Small team will attempt to test the field equipment and obtain water samples for field analysis. Goal is to test the equipment and develop/alter the field work as needed to obtain useful field results, both in equipment deployment and in obtaining transition zone water samples from the subsurface of the mudflats and from the subsurface sediments in Slip 6.

1.3 Problem Definition/Background

1.3.1 Introduction.

The Rhone Poulenc facility in Tukwila, WA, is located along the Duwamish River, and has boundaries with both the Duwamish River and Slip 6. The site has documented contamination of the soils and ground water, and the purpose of this sampling is to determine whether available tools for sampling the ground water to surface water transition zone can be used to further delineate the migration of ground water contaminants to the river. Some of the main contaminants documented at the site include toluene, copper, and high pH (over 12 in some areas). The sampling will be conducted with manual field equipment on the shoreline (mudflats during low tides), and with geochemical parameter meters and field kits. In addition, the EPA Region 10 Dive Team will be using seepage meters placed on the bottom sediments, at a depth of about 20 feet of water depth during a falling tide.

1.3.2 Objective and Scope.

The objective of the EPA sampling is to provide EPA with field tests and data using these field tools at this facility and in the general Duwamish River environment.

1.4 Project/Task Description

Sampling along a transect on the mudflats between the Rhone-Poulenc site and the Duwamish River and in subtidal areas in Slip 6 and the Duwamish River. The general location of the proposed samples are shown in the attached map of the site (not in the electronic format).

ACTIVITY	DATE
Sample Collection	April 2 and 3, 2002.
Number of samples	Depends on site, but if proposed system works as planned, then will try at least one sampling location every 50 feet along the mudflats area. Subtidal seepage samples estimated as 25 per day
Completion of Sample Analysis	On the same field day.

1.5 Data Quality Objectives (DQOs) and Criteria for Measurement Data

Obtain transition zone ground water samples and obtain geochemical parameters to compare between locations sampled. Attempt to determine whether this type of field equipment will work at this site and whether it would be worth to do more sampling for laboratory analysis. The data will be field parameter data (pH, electrical conductivity, Dissolved Oxygen, Eh, and temperature), and each parameter will be within the accuracy of the instruments. The measured parameters will be compared to those at the other sampling sites along the mudflats transect and the subtidal seepage meter transect data (EPA Region 10 Dive Plan dated March 26, 2002). The dive team may also attempt to obtain differential hydraulic head from mini-piezometers, using a differential manometer, if time permits. One expectation is that using these field parameters the data obtained will allow interpretation of any discharges which have a different signature from others nearby, indicating a different quality discharge plume at those locations. One additional measurement that will be attempted is to do field tests for copper with a field kit. It is unknown whether the sampling systems will work to obtain water samples at this site, or if the copper concentrations in these samples will be within the detection range of the field kit.

1.6 Special Training Requirements/Certification

None required.

1.7 Documentation and Records

Field notes, photographs of area and tools, locations of sampling points with either a measuring tape to a permanent fixture (pier piling) or with a GPS (Global Positioning System), or, for the subtidal samples, with the dive team AquaMap systerm for future resampling of those locations.

2 MEASUREMENT/DATA ACQUISITION

2.1 Sampling Process Design (Experimental Design)

Nearshore samples will be taken using the "MHE Push-Point Sampling Tool" (see attached description and Figure 1). Tool is pushed into the subsurface to attempt to access the ground water within the ground water / surface water transition zone, pump it up to the surface and do field analysis for selected parameters which may indicate discharge of ground water and different water characteristics along the transect (pH, electrical conductivity, Dissolved Oxygen, Eh, and temperature). If possible to obtain enough water field tests for copper may be done using field kits as available. Subtidal samples will be collected using seepage meters and analyzed for the same parameters. Additional tests of the push-point sampler and field tests with minipiezometers may also be field-tested to attempt to obtain additional water samples at different depths and to determine vertical gradients.

2.2 Sampling Methods Requirements

Sampling will be adapted as necessary to obtain water for analysis. The basic method is as documented in the MHE Push-Point Sampling Device Operators Manual Ver. 1.02 dated 5/13/00 (see general description attached). The seepage meter techniques have been adapted from the original work of David Lee and John Cherry (A Field Exercise on Groundwater Flow Using Seepage Meters and Mini-Piezometers, Journal of Geological Education, 1978, v.27, pp. 6-10), and will be followed with the following adjustments: Bags will not be partially filled before deployment since net flow rates are not being measured (the goals are to detect the hydraulic connection and then to collect a ground water sample to compare the analytes described above with surrounding surface and transition zone water); smaller buckets to make them more maneuverable by the USEPA scuba divers; bags are from a differerent manufacturer.

2.3 Sample Handling and Custody Requirements

No field samples expected to be shipped to laboratory.

2.4 Analytical Method Requirements

Field tests for geochemistry indicator parameters and copper.

2.5 Quality Control Requirements

None other than following field tests calibration methods.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

This section does not apply to this project. These requirements are met by the EPA OEA Manchester Lab facilities (per Andy Hess, provider of the instrumentation)

2.7 Calibration Procedures and Frequency

Calibration will be performed when appropriate prior to use of field instruments following the procedures found in equipment manuals.

2.8 .Reports to Management

A draft report will be prepared to document the results of this investigation. A final report containing the data, calculations, and conclusions will be prepared. A separate dive report will be prepared that briefly summarizes the sampling results (but focuses more on the dive safety issues and the completion of objectives).

A Field Exercise on Groundwater Flow Using Seepage Meters and Mini-piezometers*

David R. Lee
Department of Earth Sciences and
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Waterloo, Ontario N2L 3G1

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Abstract

Basic principles of physical hydrogeology and the nature of the hydrologic interactions between groundwater and surface water can be convincingly demonstrated in the field using two inexpensive and easily-constructed devices known as the miniature piezometer and the seepage meter. These instruments have been successfully used during a hydrogeology field course at the University of Waterloo and have been adopted as a routine teaching aid. Seepage meters and miniature piezometers are inserted in the sediment of shallow areas in lakes, estuaries, or streams. In a matter of a few hours, the devices can be installed, monitored, and removed. Information on the direction and rate of groundwater flow can be obtained. Hydraulic conductivity can be measured using several types of tests. Samples of the groundwater can be collected and, with field measurements of parameters such as specific conductance, dissolved oxygen, pH, and chloride, comparisons between groundwater and surface water quality can be made. Student investigations can include the identification of groundwater inflow, or outflow areas in lakes, streams, or estuaries, measurement of the spatial and temporal viarations in seepage flux through bottom sediments, and identification of zones of subsurface pollutant migration into surface waters. A day of equipment preparation and a preliminary site visit are prerequisites to the student field activities. Materials for a seepage meter and a miniature piezometer can be acquired for less than 25 dollars.

Key Words: education, hydrogeology, groundwater, limnology, hydrology, water quality, contaminant, seepage, field exercise, lake, stream, estuary.

Introduction

This paper describes the use of two simple inexpensive devices that enable students to measure the flow of groundwater and to demonstrate for themselves some of the basic principles of hydrogeology. A half-day field trip to a shallow body of surface water, preferably with a sandy bottom, makes it possible for students to acquire data that can serve as an impressive indication of the dynamic nature of groundwater flow in a natural setting. The methods are rapid and direct and provide information that cannot otherwise be obtained even if expensive drilling equipment is available. The exercise involves the use of seepage meters to measure groundwater flow rates and the use of manually-installed miniature piezometers to measure hydraulic head (groundwater potential) and hydraulic conductivity. These methods have been used during field experiments in a groundwater hydrology course at the University of Waterloo and as a means of investigating groundwater-flow conditions in lake- and streambeds. The devices are also being used in current research projects, including thesis studies by undergraduate and graduate students.

The basic elements of groundwater flow are related through the Darcy equation,

$$Q = A \frac{dh}{dl} K.$$

Q is the flux of groundwater (volume/unit time), A is the area through which flow occurs, dh/dl is the hydraulic gradient (the change in hydraulic head over a distance along the line of flow (unitless)) and K is the hydraulic conductivity of the material (usually expressed as cm/s). Hydraulic head is a measure of the energy per unit weight of the groundwater. Textbooks on hydrogeology such as Todd (1959), Davis and De Weist (1966) and Domenico (1972) present more detailed discussions of the Darcy equation and its significance in groundwater studies.

Figure 1 shows schematic illustrations of groundwater flow near lakes, in lake bottoms, and in stream bottoms. The flow systems are represented by isopotential lines (contour lines of hydraulic head) and arrows showing the direction of groundwater flow. In lake bottoms and streambeds, groundwater flow is upward, downward, or horizontal but is rarely non-existent. The direction and rate of flow is dependant on the physiography, texture and stratigraphy of the subsurface materials. Locally, the flow in streambeds and lake bottoms can vary dramatically, thus providing a variety of observational conditions within a single study area.

The two devices described below provide information on the flow net and on the flux and velocity of water moving along the flow lines at and near the interface. The seepage meter and the minipiezometer also provide a means of sampling the water that is either leaving or entering the groundwater zone beneath the lake or stream. This can often serve to demonstrate the influence

*This work was sponsored in part by a research agreement with Environment Canada.

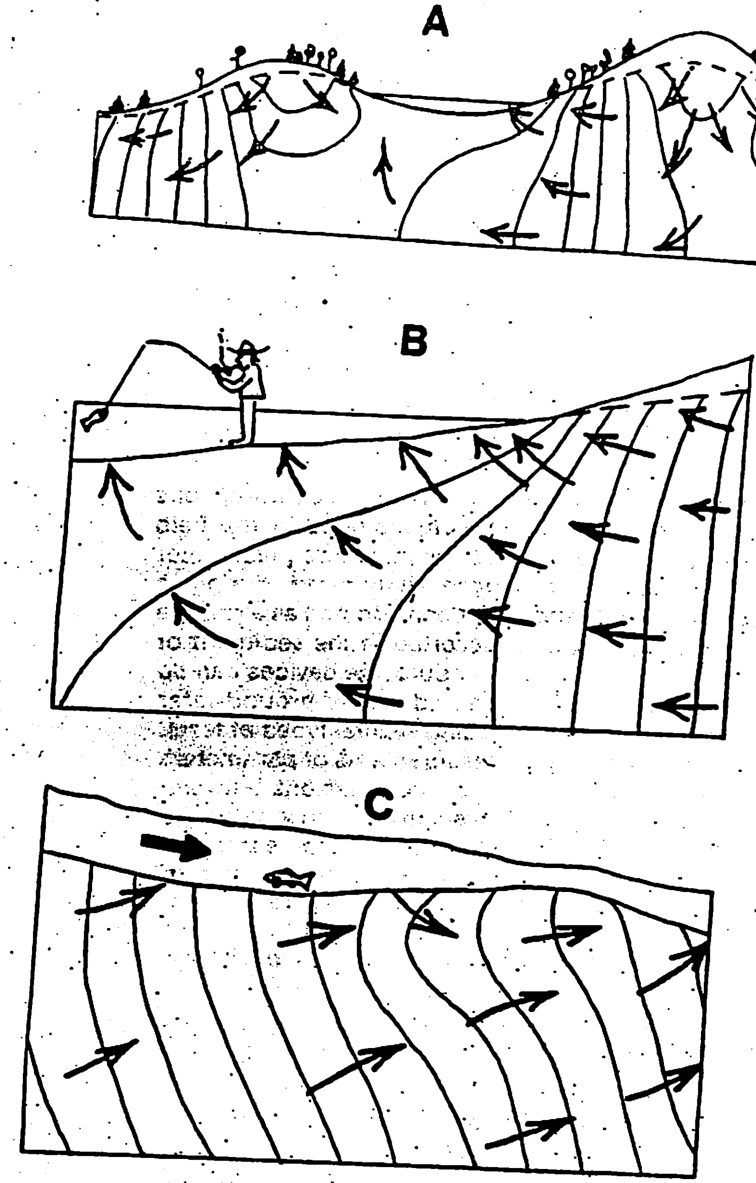

Fig. 1. — Idealized sections showing groundwater flow near bodies of surface water. A, topographic highs are recharge zones and the topographic lows (often occupied by lakes or streams) are discharge zones; B, pattern of groundwater discharge into a lake or estuary; C, longitudinal section of a streambed indicating flow into the sediment where the streambed is concave. (A modified from Winter, 1976; B modified from Lee, 1977; C modified from Vaux, 1968)

of groundwater on surface-water quality. In some cases it is possible to demonstrate that pollutants are fed to lakes or streams by groundwater seepage.

Miniature Piezometers

Piezometers are used to measure the hydraulic head in geologic materials that are saturated under positive pressure. They consist of pipes with slotted tips or well points on the end. Piezometers are normally installed in boreholes drilled by power auger, wash-boring, rotary drill or cable-tool equipment. Piezometers installed at depths between several meters and many tens of meters below ground surface have been used routinely by hydrogeologists and soil engineers for several decades. The miniature piezometer (mini-piezometer) is a similar device but is smaller in size and is installed manually.

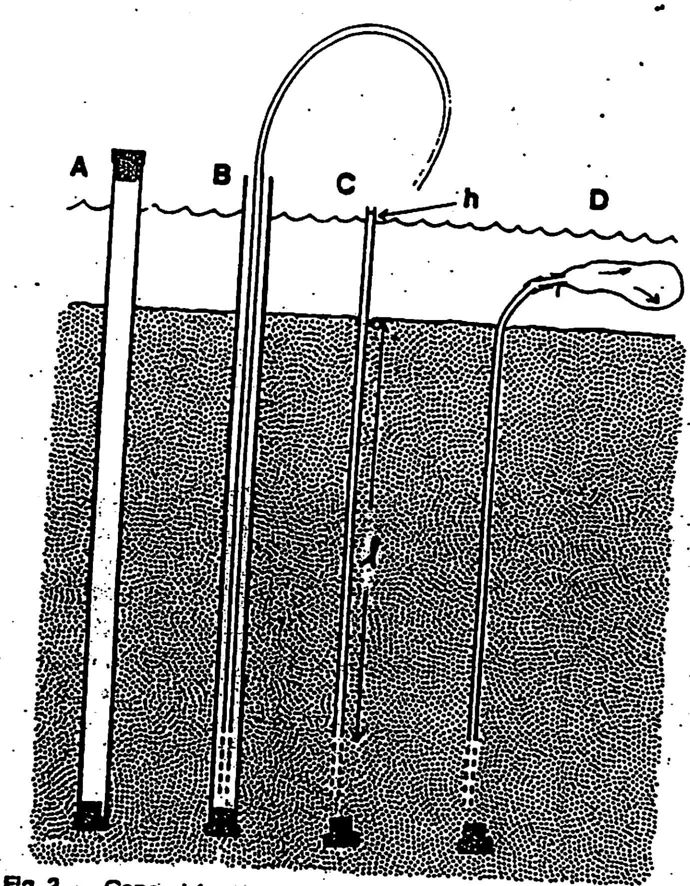

Fig. 2. — General features and method of installation of a mini-piezometer. A, casing driven into the sediment; B, plastic tube with screened tip inserted in the casing; C, plastic tube is a piezometer and indicates differential head (h) with respect to the surface water; D, plastic bag attached to the piezometer collects sediment-porewater. (See text for details)

Figure 2 shows the general features and method of installation of the mini-piezometer. The piezometer consists of a 0.31 cm ID translucent polyethylene tube (approximately $0.12/m) with a perforated tip wrapped with 0.2 mm nylon mesh netting or fiberglass cloth. The netting protects the tip from influx of sediment. The piezometer is installed using a 1.7 cm ID steel pipe that is driven into the bed by hammer or vibrator. The casing pipe is loosely fitted with 1.4 cm (5/8 inch) lag bolts at each end. When the steel pipe is driven to the desired depth the plastic tube is inserted and held in place as the pipe is pulled out. The bottom lag bolt remains in the sediment near the piezometer tip. Raised above the water level, the translucent tube shows the head differential with respect to the surface water.

Small differences in hydraulic head relative to the surface water are measured using a manometer that overcomes the difficulties of observing head differences that are slightly above or below the level of the surface water. The principle of the apparatus is indicated in figure 3A which shows how the difference in head between the piezometer and the surface water may be elevated and measured accurately. The equipment needed to measure this differential head in mini-piezometers is shown in figure 3B. The meter stick is attached to a rod and installed vertically next to the piezometer. The apparatus is prepared for use by blowing water out of the tygon tube using a rubber suction bulb. The bulb is squeezed and released slowly allowing water to rise to a static level. The

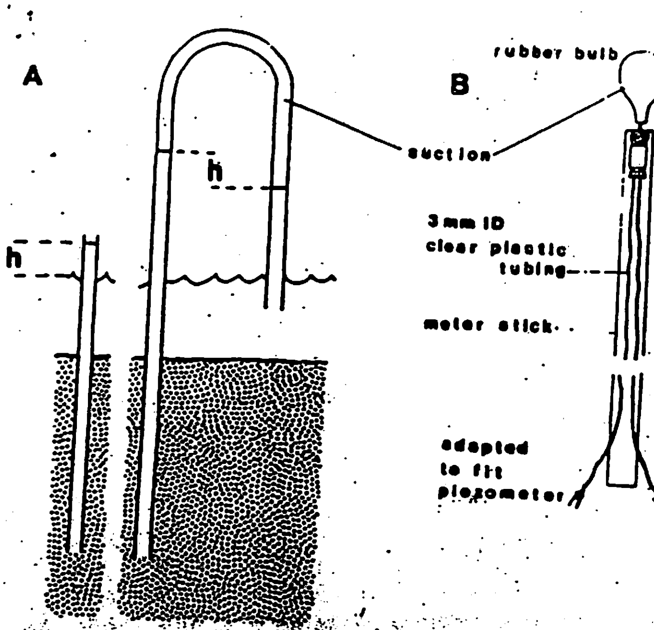

Fig. 3. — The manometer used to measure differential heads in minipiezometers. A, principle of operation; B, the field apparatus.

levels in the two tubes are compared to be sure no bubbles of air are causing different heads in the two tubes. One end of the tube is then attached to the piezometer tube and the other is left in the overlying water. When the water levels in the two tubes reach static levels, the differential head, Δh, is read on the meter stick. The vertical hydraulic gradient is $\Delta h/\Delta \ell$, where $\Delta \ell$ is the depth of the piezometer screen below the sediment-water interface.

To measure the hydraulic conductivity of the sediment adjacent to the piezometer tip, two types of tests can be conducted, a falling head test and a constant head test. For the falling head test the piezometer tube is extended vertically above the surface-water level and then filled with water to a condition of overflow. The overflow condition is discontinued at a time that is recorded as t initial. The rate at which the water level in the tube declines is then recorded. This can be facilitated by taking stop-watch readings of times at which the water level passes marked intervals on the tube. If the hydraulic conductivity is very high, the rate of water-level fall will be very rapid. Increased accuracy can be obtained if the fall distance is lengthened by extending the tube a couple meters above the surface-water level or by feeding water to the piezometer from a larger diameter reservoir with marked intervals. A constant head test can be performed by placing a known volume of water in a plastic bag attached to the submerged tube. The hydraulic head in the submerged bag is the level of the stream or lake level. The change in volume of water in the bag over a recorded time interval is measured. Example results and calculation procedures are summarized in Table 1. The derivations of the equations used in this analysis were first presented by Hvorslev (1951) and have been summarized by Lambe and Whitman (1969). The constant head and falling head formulas are based on significantly different assumptions. Comparison of hydraulic conductivities determined by these two methods can be an interesting endeavor.

Where the hydraulic gradient is downward, groundwater from the piezometer can be collected using

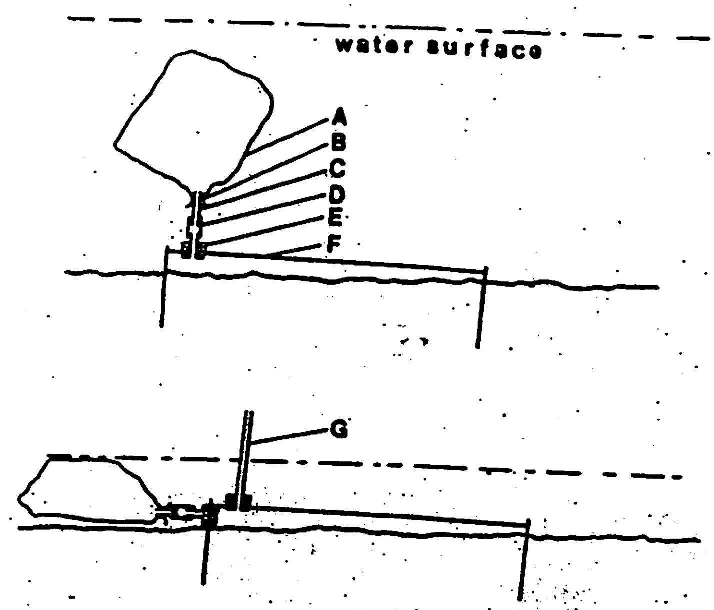

Fig. 4 — Full section view of seepage meter showing proper placement in the sediment. A, 4 liter, 0.017 mm membrane plastic Baggies Alligator bag (open end was heat sealed); B, rubber-band wrap; C, 0.64 cm inside diameter, 6 cm long, polyethylene tube; D, 0.79 cm inside diameter, 4.5 cm long, amber-latex tube; F, 15 cm x 57 cm diameter epoxy-coated cylinder (end-section of a steel drum); G, 0.64 cm inside diameter, polyethylene tube long enough to reach above the surface water. E, No. 5½ one-hole rubber stopper with polyethylene tube.

a suction bulb or hand-operated vacuum pump connected to a bottle. Where the gradient is upward samples can be obtained by simply letting water discharge from the piezometer tube. Where the gradient is weak or the material poorly conductive, the screened area of the piezometer tip must be increased and suction must be applied to obtain water samples.

Seepage Meters

Seepage flux between the groundwater and the overlying surface water can be measured directly by covering an area of sediment with an open-bottomed container and then measuring the time and change of water volume in a bag connected to the container (Lee 1977). Two of these devices, known as seepage meters (Fig. 4), can be made by cutting 15-cm-long, end-sections from a 0.208 m^3 (55 gallon) metal drum. Seepage meters can detect flux as low as 0.001 cm^3/m^2 s (about 0.1 mm/day) if the bag is left connected for a day or longer. In water over 20 cm deep, a single tube through the top of the seepage meter serves both as a vent for any gas released from the sediment and as a connection for the measuring bag. In shallow water an additional outlet tube on the side of the seepage meter permits the bag to be submerged as it must be to maintain the same piezometric head in the seepage meter and in the surface water.

In use, the seepage meter is pushed slowly into the sediment and tilted slightly so that the vent will function properly (Fig. 4). Unless the sediment surface is soft or irregular, it is often unnecessary to push the seepage meter more than 8 cm into the sediment to obtain an adequate seal. The stopper with tube is then twisted into cylinder hole. Where flow is upward, it is unnecessary to

Table 1. Sample field data and calculations.

Piezometer observations

Piezometer number: P1 Depth of screen below sediment: 1 m

Time	Δh,mm	Gradient $\Delta h/\Delta l$	Elapsed time, min	Volume change, cm^3
1630	35	.035	—	—
1650	33	.033	—	—
1739	36	.036	—	—
1705-1723	—	—	18	+12

Hydraulic conductivity calculation: Assuming a case G screen (Hvorslev 1951),

$$K_h = \frac{q \ln [(mL/D)+(1+(mL/D)^2)^{.5}]}{2\pi L H_c}$$

, where

D = diameter, intake, sample (cm)
L = length, intake, sample (cm)
H_c = constant piezometric head (cm)
q = flow of water (cm^3/s)
t = time (s)
m = transformation ratio, $(K_h/K_v)^{.5}$ assumed to equal 1*
ln = 2.3 $\log_{10}$.

Therefore K_h =

$$\frac{(12\ cm^3/1080\ s)\ LN\ [(10\ cm/.31\ cm) + (1+(10\ cm/.31\ cm)^2)^{.5}]}{2\pi (10\ cm)(3.5\ cm)}$$

$= 2.1 \times 10^{-4}$ cm/s

Seepage meter observations

Seepage meter number: SM 1
Depth of water: 0.2m
Sediment type: sand and organic matter

Time	Volume change, cm^3	Elapsed time, min	Seepage flux, $\mu m/s$	Hydraulic conductivity, cm/s
1630-1648	+126	18	+.450	1.3×10^{-3}
1650-1736	+355	46	+.496	1.5×10^{-3}
1739-1752	+ 94	13	+.465	1.2×10^{-3}

Seepage flux calculation:

$$Q, \mu m/s = \frac{(\text{volume change, } cm^3)\ 0.0643}{(\text{elapsed time, min})}$$

$$= \frac{(126)\ 0.0643}{18} = 0.450\ \mu m/s$$

Hydraulic conductivity calculation:
From the Darcy equation K = v/S, where
v = Darcy velocity
S = hydraulic gradient, $\Delta h/\Delta l$
K = hydraulic conductivity

$$\text{Therefore } K = \frac{0.450\ \mu m/s}{0.035} = 1.3 \times 10^{-3}\ cm/s$$

* The effect of this assumption is small (e.g. if m = 10, K_h = 2.7×10^{-4} cm/s; if m = 1000, K_h = 3.9×10^{-4} cm/s.

add a known volume of water to the measuring b before connecting it to the seepage meter.

The Darcy velocity, v, (volume per unit area per ur time) is calculated from the relation $0.0643 V \div t = v$, wher V is the volume of water (cm^3) entering or leaving the ba and t is the elapsed time (min). The Darcy velocity expressed as micrometers per second (1 $\mu m/s$ = 8.6 cm/day). The factor 0.0643 converts units of time volume, and area covered by a seepage meter (0.255 m^2 to equivalent units of velocity ($\mu m/s$) or seepage flu (cm^3/m^2 s). The average linear interstitial velocity is equa to the Darcy velocity divided by the porosity of the sediment. For most sandy sediments, porosities are in the range of 0.3 to 0.4 (expressed as a fraction).

Student Activities

Students from the University of Waterloo used these techniques to investigate the migration of tritium-contaminated groundwater to a small lake and stream in an experimental watershed at the Chalk River Nuclear Laboratories in eastern Ontario. To minimize the number of pieces of equipment required, this exercise was combined with stream-flow metering so the students could rotate from one activity to the other. Each student installed a piezometer and a seepage meter and measured piezometric head during seepage-measurement intervals ranging from 10 to 45 minutes. Because of the difficulty of removing deeper casings by hand, most students elected to emplace their piezometer 0.6 to 1 m into the sediment. Each student conducted a constant head test to determine the hydraulic conductivity of material near the piezometer screen, and then removed the seepage meter so that subsequent students could install the equipment themselves.

The study sites met the following selection criteria:
Wave height less than 0.3 m;
Current speed less than 0.2 m/s;
Firm sand with very little gravel and cobble; and
Water depth 0.1 to 0.6 m.

Preliminary measurements were made to be sure the students could install the equipment and find seepage rates high enough to complete the exercise in 2 to 3 hours. Because seepage rates are generally highest near the shore, as illustrated in figure 1B, and because shoreline areas were accessible by wading, students worked within 10 m of the shoreline.

Data collected by one student and some sample calculations are shown in Table 1. Piezometric head and seepage rate generally decreased with distance from the lakeshore but seepage rates were quite variable in the streambed. Current effects probably accounted for the variability of replicate seepage measurements in the stream. Streambed heterogeneity probably caused variability between points. No zones of downward seepage were found in either the lake or the stream.

Direct measurements of seepage flux, made by the students, showed that groundwater flowed into the lake along the northern shore. A pore-water constituent (in this case tritiated water) indicated that this seepage water is contaminated by tritium, contained in waste waters pumped into disposal pits located about 800 m north of the lakeshore. The use of seepage meters and mini-piezometers thus enabled the students within a very short time to draw conclusions with regard to the occurrence and source of contaminants entering the lake. Analysis of water from mini-piezometers in the nearby streambed showed no tritium contamination despite the presence of considerable tritium in the stream itself.

The dynamic nature of the groundwater regime was demonstrated in a visibly impressive manner by filling of the measuring bag attached to the seepage meter. All but 2 of 14 piezometers functioned properly as indicated by raising and lowering the piezometer tube and watching the water level fall or rise to a static level and by the constant-head response tests. Failure to obtain responsive piezometers was due to lifting of the piezometer tube while pulling the casing out of the sediment and consequent loss of the nylon-mesh screen.

We anticipate that a similar approach could be used by others to teach general principles of hydrogeology. This exercise could be included as a part of an introductory course in hydrogeology. It could also be used in hydrology, limnology, geomorphology or sedimentology courses. It could serve as a springboard for student projects designed to determine the importance of the groundwater component to the water budget of a lake or pond, to identify contaminant migration from groundwater to surface waters, to study the effects of seepage flux on sediment chemistry, or to study the role of groundwater in fluvial erosion and deposition. Because these topics have only recently begun to receive research attention, this work offers an opportunity and a freshness which is attractive to students.

Planning the Field Exercise

Sandy shores of gravel-quarry ponds, lakes, reservoirs, and estuaries are ideal sites for these exercises, but the importance of making preliminary measurements to identify suitable sites cannot be overemphasized. Seepage rates must be high enough so that volume changes of at least 50 cm^3 can occur in the measuring bag in 1-2 hours. The sediment should not contain rocks which will bend piezometer drive-casings. Strong wave action and currents interfere with accurate measurements of seepage, although piezometers would probably not be affected adversely. Mud bottoms ma have sufficient flow to permit flux measurement in hours.

In estuaries, where tidal fluctuations induce seep flux through sediment, it may be helpful to consult tables before planning a field exercise. At low tide, highest rates of upward seepage and the stron upward gradients occur (Lee 1977), and it is easie install seepage meters at this time. Estimates of seepage flux will require measurement through an en tidal cycle.

In streams where surface-water velocity is low a especially in sandy areas, these methods can be us successfully. In other stream environments, however may be difficult to find suitable demonstration sit Downward seepage in streams may be induced whe permeability or depth of gravel increases in the directi of streamflow or where the longitudinal bed profile concave (Vaux 1968). These factors, heterogeneity an current, make data from streambeds more difficult interpret than comparable data from quieter waters.

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MHE Push-Point sampling tools by Mark A.Henry - May 13, 2000

A new tool and sampling methodology have been devised for collecting pore-water samples from beneath beaches and surface water bodies. The use of this technology enables a single investigator or small team to rapidly gather pore water samples at or near the interface between groundwater and receiving bodies of water. From a research perspective the information gained in analyzing these samples may be very helpful in understanding the geochemical nature of this transition zone and the biological processes at work.

This methodology has been used very successfully to locate the expression of contaminated groundwater venting into several lakes in Michigan. The technique involves the use of an MHE 27" push-point sampling device (PP27), 1/4"OD X 1/8"ID Tygon tubing, and 50 ml-100% polyethylene syringes or a peristaltic pump. The PP27 is a rigid 1/8" diameter stainless steel probe that is screened at one end and ported at the other to allow the collection of pore-water with a syringe or peristaltic pump. In this methods simplest form, the investigator would walk along a beach or in shallow water paralleling the beach, and at periodic intervals push (by hand) a decontaminated PP27 into the sand or sediments with a twisting motion until refusal (usually 6-18"). Then the screened zone is exposed and pore water samples are withdrawn at "low-flow sampling" collection rates using a disposable syringe connected by a length of Tygon tubing. Usually, only 30-50 ml of water withdrawal is necessary to "develop" this miniature "well"; this equates to ~ 20-35 volume exchanges through the PP27. Subsequently drawn water is usually non-turbid and suitable for dispensing directly into sample containers or instruments. A 3-dinensional sampling array is possible within the sediments and the water column. The PP27 is easily decontaminated in the field but if the investigator has several of the inexpensive sampling devices on-hand, sample collection along a transect can be a very rapid process. When 100% polyethylene syringes are employed, samples may be collected and stored temporarily within the syringe by placing the full, sealed syringe in a cooler. Once the sample collection has been completed, the investigator can process the samples in a controlled environment. As an added benefit, it is possible to use the sample-filled syringes for on-site headspace analysis of VOC's using a field GC - information that be used to direct an investigation in real-time. If the syringe is half-dispensed and refilled with air, resealed and agitated , the headspace in the syringe above a known volume of water can be quickly analyzed.

The Michigan Department of Environmental Quality (MDEQ) uses an enhanced variation of this method. As samples are being collected, some of the pore-water is immediately dispensed into field analytical equipment for measurement of "stabilization parameters" such as dissolved oxygen, pH, conductivity, redox, and temperature, or analytes such as dissolved iron, sulfide, etc. The MDEQ investigators were able identify and map the expression of a groundwater plume venting into Lake Michigan and several inland lakes using this methodology and/or these techniques and SCUBA gear. Furthermore, the MDEQ couples its sampling with locational information obtained using sub-meter accuracy global positioning system (GPS) equipment. Plotting the geochemical data onto an accurate GPS representation of the sampling locations and predominant local features produces a precise plume expression map. GPS technology allows investigators to reliably relocate previous sampling locations for additional study and accurately combine/compare data from multiple sampling events. Imagine the possibilities.

Figure 1

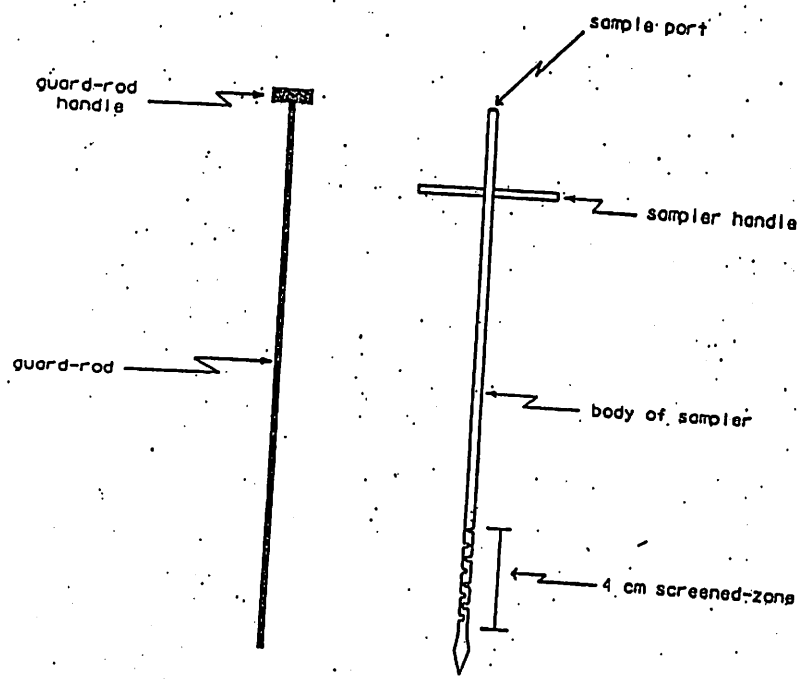


Fig. 1a
disassembled sampler

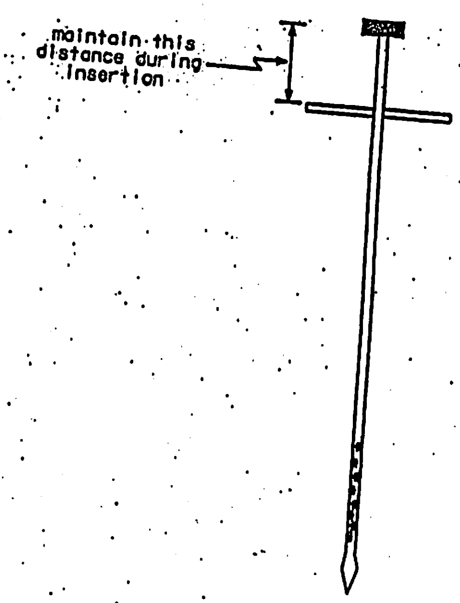
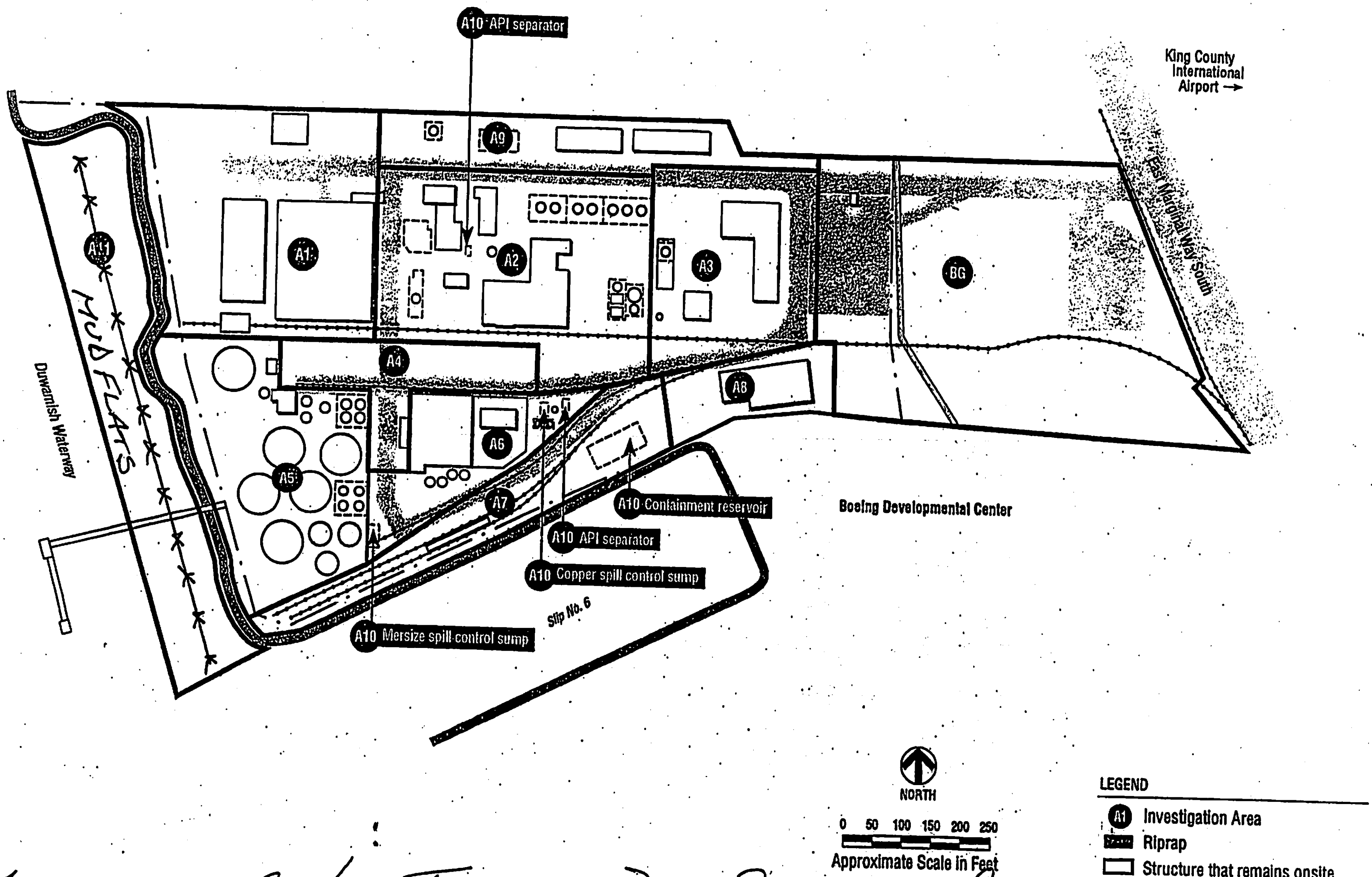


Fig. 1b
assembled sampler



MARCH 2002 - GW/SW TRANSITION ZONE SAMPLING PLAN

NOTE: Investigation Area A10 consists of a reservoir, sumps, and API separators located across the Facility.

(BASE MAP FROM RHONE POULENC RFI)

Figure 2-1
RFI Investigation Areas

SEDIMENT SAMPLING APPROACH

Historical processes: LOADING/UNLOADING (CAUSTIC, VBL, LIGNIN)

Sediment analysis: INORGANICS, SEMIVOLATILES, PESTICIDES/PCBs, CONVENTIONAL PARAMETER

Sample depths: ROUND 1 : 0-0.5 FOOT   ***Number of sediment samples:*** 7

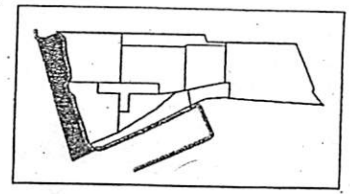
ROUND 2: 0-2 CM

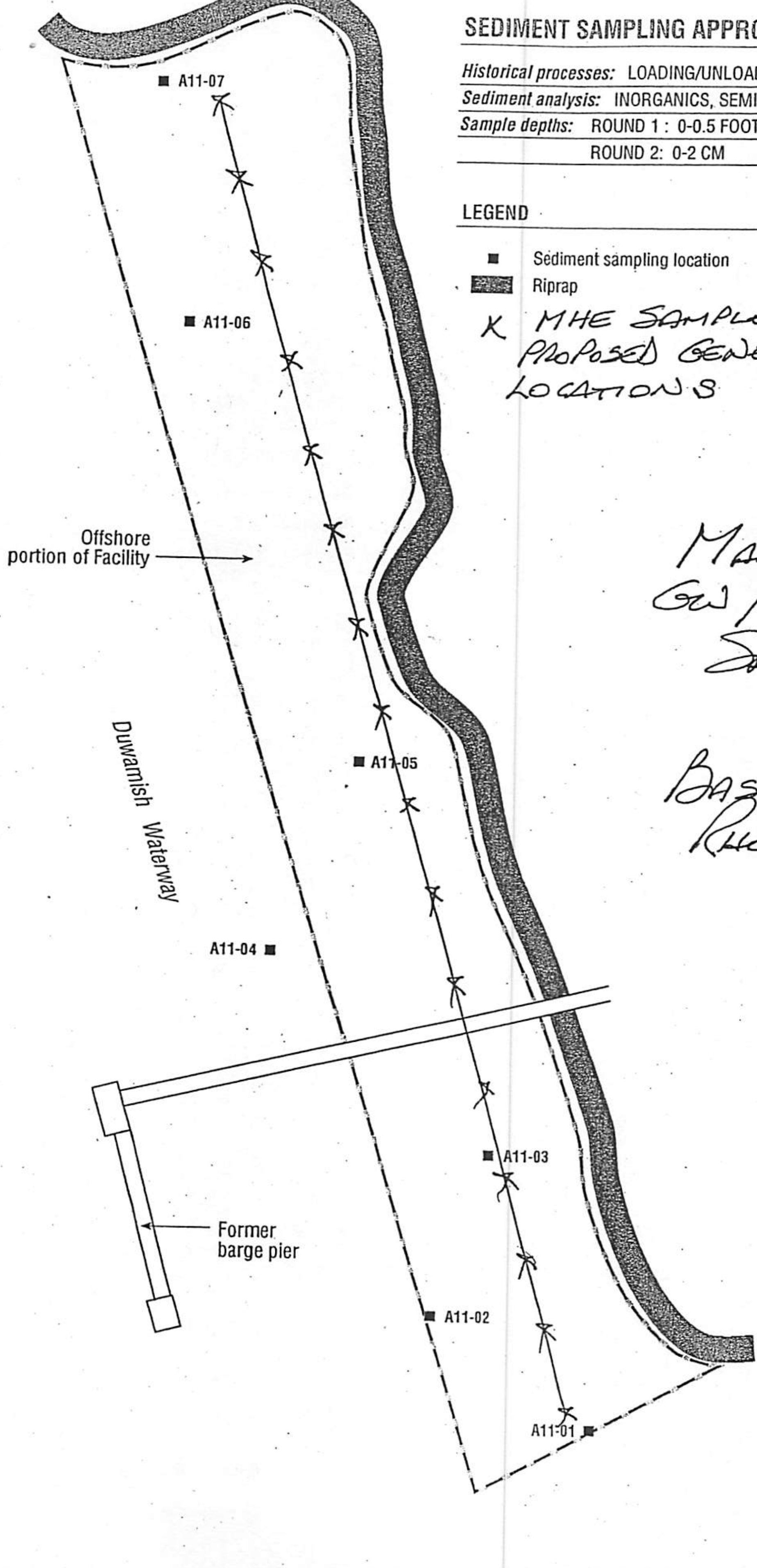
LEGEND

■ Sediment sampling location

Riprap

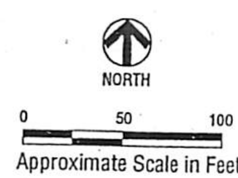
X MHE SAMPLER PROPOSED GENERAL LOCATIONS





MARCH 2002
GW / SW TRANSITION ZONE
SAMPLING PLAN

BASE MAP FROM
RHONE POULENC RFI
(FIGURE 4-53)



Notes:

1. *Summary of statistics for parameters detected in sedin*
2. *Mean includes nondetections at half of the detection lir*
   This is a result of high detection limits caused by matri

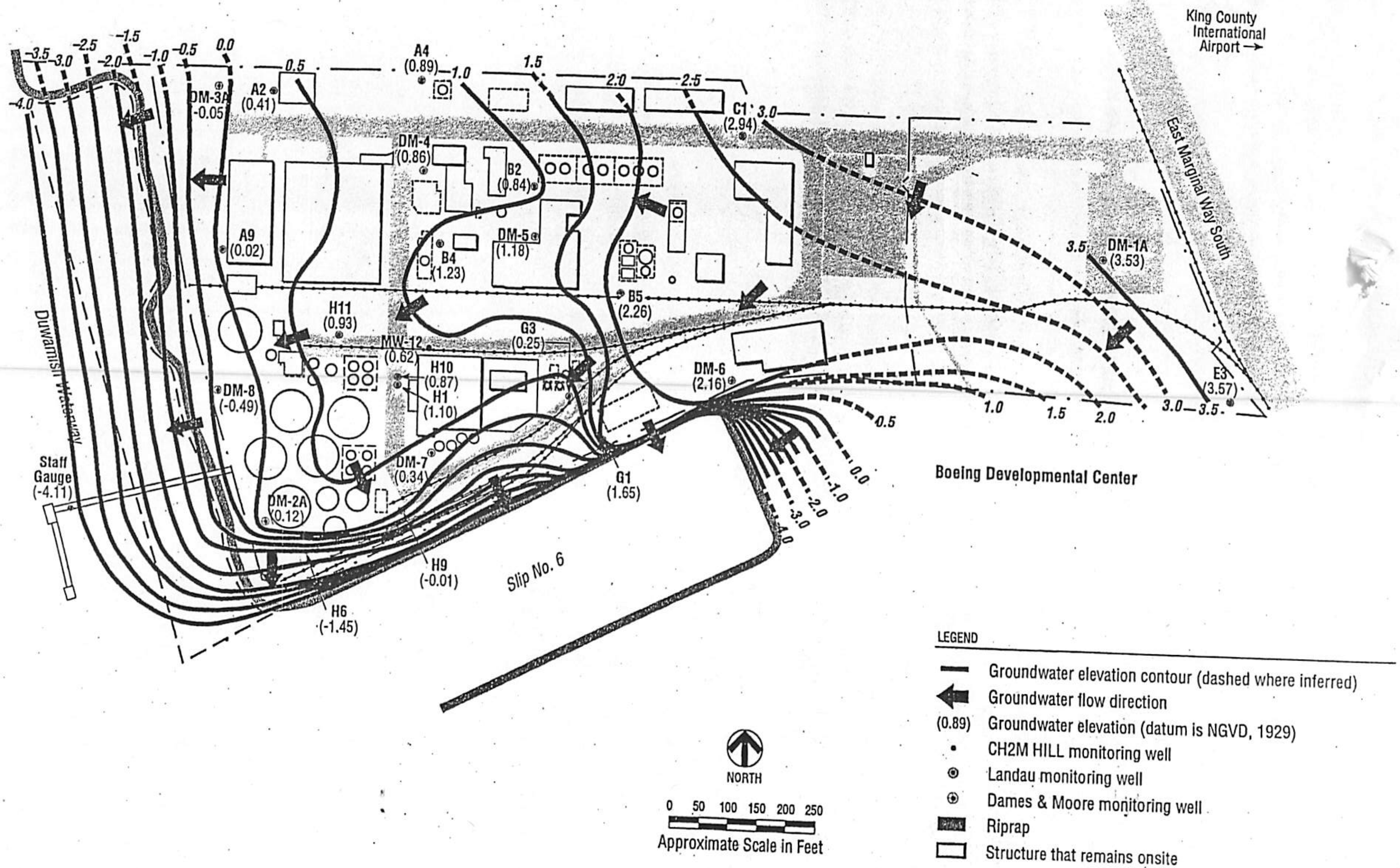


Figure 4-18

Groundwater Contours, Upper Aquifer Low Tide, 2/4/94 at Approximately 1745